Book Reviews

Integrated Life-Cycle and Risk Assessment for Industrial Processes

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With the coming European regulatory focus on products, through the integrated product policy, IPP, and on chemicals, through the new chemical legislation, the boundary region between the product and the chemical domains is likely to gain prominence over the years to come. The book by Sonnemann, Castells and Schuhmacher addresses this situation very timely by discussing the possibilities and limitations of an integration of the analytical tools for assessment of products and chemicals, LCA and environmental risk assessment (ERA).

The book prepares the reader for a deeper understanding of LCA and ERA, their similarities and differences in methodology and domain of application. It is intended as a textbook for graduate and postgraduate students, and the didactic aim is supported by an illustrative case study concerning a municipal waste incineration plant located in Tarragona in Catalonia. The case study is treated throughout the book and is taken up at the end of each chapter to illustrate central parts of the theory which has been presented. In addition, each chapter has a section with questions and exercises to support the use of the book as a text book in university courses or to be used by the solitary reader to check the understanding of central points in the text.

Opening with an introduction to Basic Principles in Environmental Management, the book briefly presents the strategies, concepts and tools in the environmental management toolbox, from legislation over standards and procedural tools like EIA to analytical tools such as LCA and ERA.

The two following chapters take the reader through LCA and LCIA from the early beginnings up to the current status. The review reflects the authors' participation in international method development work and the presentation is based on the latest developments within ISO standardisation, SETAC working groups and the UNEP/SETAC Life Cycle Initiative. The review places its main weight on LCIA in accordance with the overall goal to investigate the integration of ERA and LCA. In the presentation of the goal and scope definition, the recommendation on choice of allocation principles has disturbed me. Rather than convey the clear preferences given in ISO 14041 (first system expansion, then allocation according to a relevant technical criterion, and finally according to an economic criterion), the authors present several examples of possible criteria (not mentioning system expansion, which is actually used in some of the cases presented throughout the book) and leave it to the reader to choose. This being said, the chapters on LCA and LCIA together give the reader a good updated review, particularly on LCIA.

The chapter on ERA provides a concise introduction to the fundamental principles of hazard identification, exposure assessment for humans and ecosystems, effects assessment, risk characterisation and risk management. It takes a deeper look at the Impact Pathway Analysis (IPA), applied in the ExternE project as a basis for modelling of human health damage. The multi-tier approach applied in current chemical risk assessment is not explicitly mentioned, although the tendency to apply conservative estimates in ERA is discussed. The application of several tiers with increasing accuracy, but also increasing data demand at higher tiers, might inspire LCIA of chemicals.

A chapter on Uncertainty Assessment provides a rather detailed presentation of the principles and virtues of Monte Carlo Simulation leading up to the presentation of the main feature of the book – the integration of environmental risk assessment and life cycle assessment, to which the following two chapters are devoted.

This core part of the book is based on research performed by Guido Sonnemann as part of his PhD work to meet the need for a more environmentally realistic life cycle impact assessment through spatial differentiation and damage modelling for human health. Other current developments in the field have aimed for spatial differentiation at the level of countries (site-dependent characterisation), but the proposed integration of life cycle and risk assessment goes further in terms of spatial detail and looks at localised individual industrial activities and their specific receiving environments (site-specific characterisation). The authors acknowledge that such a detailed spatial differentiation will not be feasible for all processes in an ordinary product LCA. It will also not be relevant since most of the processes will only contribute marginally to the total environmental impact from the life cycle. For *industrial process chains*, i.e. shorter life cycles (or elements of a full product life cycle) comprising those processes which are involved in a specific industrial activity, however, it may be both feasible and relevant to apply the high level of spatial differentiation.

The methodology for the integrated life cycle and risk assessment largely follows the framework of LCA supporting the choices to be made in the Goal and Scope definition and Inventory phases for industrial process chains. For the impact assessment part, several approaches from a midpoint level to damage modelling including monetisation are supported. A site-specific impact assessment is recommended for those processes which are shown by a dominance analysis to contribute most to the overall impact or damage. To supplement the site-specific approach, a site-dependent (i.e. spatial differentiation at a more regional level) impact assessment methodology is also developed for air-borne human toxicity. The main focus in the spatial differentiation is thus on human toxicity impacts, and the relevance and feasi-

bility of spatial differentiation in the assessment of impacts on ecosystems still remains a largely unaddressed issue – here as well as elsewhere.

The final chapter of the book illustrates the use of the integrated methodology on three additional cases. The strength of this book clearly lies in cases where dominant contributions to the overall impact or damage come from one or a few well known processes for which conditions of receiving environments can be known. Here, the integration of ERA and LCA can provide impact or damage predictions which are much better in accordance with what actually happens. In LCAs of ordinary products, where many processes contribute significantly, the data requirement of the integrated approach will be hard to meet. Hence, the focus on industrial process chains – an application between conventional LCA and ERA.

Overall, the book provides a good introduction to LCA and ERA, and some interesting work on the integration of the two. Its main message concerns the possibilities and relevance of site-specific and site-dependent risk assessment, not just for individual processes (in which case we are talking about ERA) but also for shorter industrial process chains, i.e. geographically well-localised parts of life cycles.

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New LCA Theses

Environmental Damage Estimations in Industrial Process Chains

Ph.D. thesis by Guido W. Sonnemann, Universitat Rovira i Virgili, 2002

Methodology development with a case study on waste incineration and a special focus on human health

Environmental damage estimations in industrial process chains need the assessment of environmental impacts in two perspectives: process chain-orientated and site-orientated. Environmental assessment tools exist for both perspectives: Life Cycle Assessment (LCA) and Environmental Risk Assessment (ERA). LCA is a fairly new chain-orientated tool to evaluate the environmental performance of products focussing on its entire life cycle. In the Life Cycle Impact Assessment (LCIA) phase, a product system's Life Cycle Inventory (LCI) results are evaluated to better understand their environmental relevance. ERA is a tool to assess the risk of chemicals. In the exposure analysis, the risk of a process at one location is evaluated. The Impact Pathway Analysis (IPA) is a method related to ERA that has been developed for the assessment of environmental damages by the terms of physical impact parameters like cancer cases. In the IPA, the physical impact parameters are usually converted into external environmental costs, but individuals may prefer other existing weighting schemes to express different types of environmental damages depending on personal values.

Products are manufactured in a ramified chain of processes. While specific tools exist for the environmental assessment of products and processes, this is not the case for the assessment of a number of industrial processes with a common functional unit such as end-of-life cycles. However, the level of sophistication in the assessment can be much higher for industrial process chains with a quite limited number of processes involved than for the life cycles of complex products. Only little efforts have been made so far to systematically explore the inherent uncertainties, interfaces and possibilities for integration and communication of the chain-orientated and site-orientated environmental assessment methods in the case of such industrial process chains. Therefore, the objective of this thesis is to find an adequate trade-off between process chain-orientated and site-orientated environmental impact assessment and to convert environmental damage estimates into meaningful results like environmental costs.

The thesis proposes a mathematical framework and a flowchart that allows spatial differentiation at different levels of detail based on the integration of LCA, ERA and IPA with environmental costs. This methodology, called 'Environmental Damage Estimations in Industrial Process Chains', puts the conventional, potential midpoint LCIA indicators in a common framework with damage, endpoint IPA indicators. As a trade-off between site-specific damage assessments and potential life cycle indicators, a currently existing site-dependent impact assessment is further developed and integrated in the methodology proposed. The site-dependent impact assessment method is based on statistical reasoning and uses representative, generic impact classes corresponding to receptor distribution and dispersion conditions. As part of the methodology development, uncertainties in the LCI and IPA are analysed using Monte Carlo Simulation. This parallel analysis permits one to show that the uncertainties in the inventory analysis are less important than those in the damage assessment.

The methods presented and the methodology developed were successfully applied in several ways to a case study on waste incineration with a special focus on human health. In a comparison of the results obtained by endpoint indicators with midpoint indicators, it was found for the situation of the case study that the midpoint indicators apparently underestimate the environmental impact of the transport processes. A new generation of integrated waste management tools seems to be feasible that takes into account the setting of the waste treatment installations and the sites affected by the transport routes, allowing in this way an overall environmental optimisation.

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